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Drawing and Knowledge Construction in Archaeology: The Aide Mémoire Project

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ABSTRACT

The Aide Mémoire Project conducted a survey and a series of observational studies in field recording and artifact illustration to understand 1) the perception of digital and by-hand drawing in archaeology, 2) how drawing contributes to the creation of mental models that allow archaeologists to understand archaeological remains and artifacts, and 3) what impact digital drawing has on the creation of these mental models. Our toolkit includes the NASA Task Load Index to assess and compare the mental load while drawing digitally or by-hand. We conclude that there are significant pedagogical, academic, and professional implications to consider when removing or replacing by-hand drawing with digital recording in archaeological methodology.

KEYWORDS

digital media; archaeological illustration; digital archaeology; archaeological methods; mental models; archival; archaeological knowledge construction

Introduction

Drawing is a problem within archaeology. Interpretive media creation such as drawing plays a central role within archaeological knowledge construction (Perry 2014), but to create an effective illustration or photograph, the archaeologist must understand the subject and convey this understanding to the intended audience for that medium. The creation of archaeological media is also pedagogical; learning to visually reproduce archaeological evidence is critical to creating the conditions of close observation that lead to a deeper understanding of archaeological remains. Yet, the exact mechanisms for creating this deeper understanding remain unclear, particularly within illustration. While among some archaeologists it is generally felt and assumed that drawing is essential to archaeological recording (James 2015; Morgan and Wright 2018), the function of media creation has been of presumptive but unproven benefit in archaeological knowledge production. While the advent of digital media creation in archaeology has been argued to create efficiencies and increase speed, accuracy, and multivocality (Roosevelt et al. 2015; Taylor et al. 2018), it has also provoked new questions regarding traditional analog methods that are central to archaeological knowledge production (Morgan and Wright 2018). Despite these new questions, there has been relatively little uptake when archaeologists have been asked to "think beyond the tool in order to consider the ways in which these tools impact upon us and our practice, shape our perceptions and alter our interpretations" (Huggett 2012, 212).

This research represents the first practical explorations undertaken based on the theoretical work described in "Pencil and Pixels: Drawing and Digital Media in Archaeological Field Recording" (Morgan and Wright 2018). To form a holistic, data-driven understanding of technical drawing in archaeology, Morgan and Wright collaborated with a field archaeologist with significant expertise in digital data capture (James Taylor) and a psychologist specializing in human-computer interaction (Helen Petrie). We named the endeavor the Aide Mémoire Project, as an allusion to the act of drawing as memory-making. While technical drawing is only one form of interpretive media creation within archaeology, we have identified it as both occupying an essential place in the understanding and recording of the archaeological record and being uniquely impacted by the digital turn. In recent years, there has been a shift toward digital tools across the range of drawing methods in archaeology, such as digitally tracing photographs, "drawing" using a total station or differential GPS, or by removing drawing entirely and replacing it with photogrammetry (see discussion in Berggren and Gutehall 2018, 128–137; Olson et al. 2013). We acknowledge that the use of the term "by-hand" can be problematic; we use "by-hand" in the idiomatic sense to indicate a lack of automated or machine assistance (see Morgan and Wright 2018 for further discussion; see also a valuable discussion of technical drawing in Sapirstein 2020). Yet, even as our methods have changed, there has been very little investigation of the implications of these changes. Our interdisciplinary research attempts to remedy this omission by incorporating multiple perspectives, drawing from methods used in user interface design and psychology to examine the shifting understanding and use of drawing in archaeology.

The Aide Mémoire Project employed an intensive, two-year program of mixed methods research regarding drawing in archaeology, including a survey, ethnographic observation, interviews, and observational studies of archaeological illustration and field drawing amongst inexperienced and very experienced archaeologists (Figure 1). The approach was holistic rather than strictly linear, meaning the methodology used for each study allowed us to learn about the advantages and limitations of the employed methods as we went along and adjust accordingly. It is important to note that what follows is a discussion of the results of the individual studies but equally an attempt to better understand how we should be approaching this type of analysis in the first place, as there is little precedent within archaeology to draw upon.

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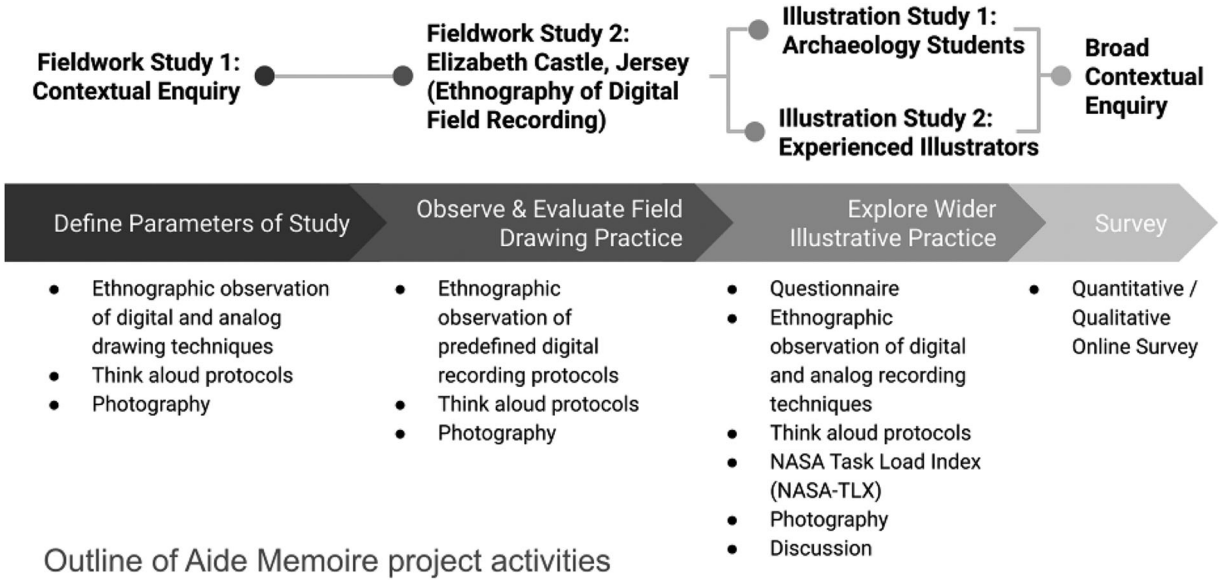

Figure 1. Outline of the Aide Mémoire Project activities detailing the various studies implemented and methods deployed.

First, we performed a contextual inquiry amongst the project members and with experienced archaeological illustrator Lesley Collett to better frame our inquiry and to demonstrate archaeological drawing methods to Helen Petrie. Our initial observations led to our ethnographic study of digital field recording at the Elizabeth Castle Project in Jersey. To widen our understanding of the role drawing plays within archaeology, we explored wider practice in archaeological illustration with relatively inexperienced students and very experienced professional archaeological illustrators. Our discussions with the professional archaeological illustrators revealed that our understanding of what archaeologists thought about drawing was relatively limited; we therefore conducted a follow-up survey on the perceptions of drawing amongst archaeologists. Each of these instances of data-gathering added more complexity to an already immense field of inquiry. In our description of this research and the conclusions we draw from our data and the broader literature regarding drawing and mental models in psychology, we show what interdisciplinary work can bring to our understanding of archaeological knowledge production but also the areas that can be further explored in the future.

Mental Models

During our interdisciplinary work, we found mental models key to understanding drawing and archaeological knowledge construction. The concept of mental models is much used in cognitive psychology and many related disciplines and has an extensive body of literature and research. Although the concept originates with Craik (1943), it was Johnson-Laird (1983) who did much to stimulate interest in mental models in psychology. He defined a mental model as "a representation of the world that is constructed from perception, memory, or imagination, and that underlies thinking" (Johnson-Laird 2013, 664). Mental models can be created from direct experience of the world through perception and action but also from narrative descriptions. Thus, he would argue that you can develop a mental model of the deposition of an archaeological site by looking at the stratigraphy, by digging it yourself, or by having someone describe it to you. By contrast, Glenberg (1999) makes the argument that mental models must also draw upon embodiment to understand cognition; this position is not universally accepted within psychology, yet it resonates with our research within archaeology. Johnson-Laird, and numerous psychologists who followed him, were interested in how mental models supported deductive and inductive reasoning, and although he emphasized that mental models depended on the semantics rather than a general syntactic framework, he concentrated on studies with simple semantics such as sentential reasoning (e.g. Trowels are made for bricklaying. Archaeologists use trowels. Therefore, archaeologists are bricklayers).

However, other psychologists and researchers in human-computer interaction are interested in the mental models people develop of real world, semantically rich domains (Rogers, Rutherford, and Bibby 1992). These tend to be much less about rigorous reasoning and more about representations of knowledge and some reasoning capabilities. Researchers have investigated mental models of everything from improvisational theatre (Fuller and Magerko 2011) to robotic assistants (Kiesler and Goetz 2002) and online privacy and security (Coopamootoo and Gross 2014; Wash and Rader 2011). One of the problems of studying mental models is that because they are so semantically specific and diverse, there are no set methods for eliciting individuals' models and no set frameworks for representing them. Research proceeds on a case by case basis, using many mixed methods approaches appropriate to the domain. Cognitive archaeologists have drawn upon mental models to make inferences regarding ancient cognition (for example Wynn and Coolidge 2016), but there have been relatively few examples of psychological examination of archaeological knowledge creation (but see Borck et al. 2020).

The embodied mental models that we construct to interpret archaeological stratigraphy are created through what Glenberg characterizes as a "mesh of affordances, action-based knowledge, and action-based goals" (1999, 86). The affordances of the tool and how it interacts with our bodies, the environment, and the interpretive subject combine to create a mental model of the archaeological remains. An embodied mental model reflects a process of investigation

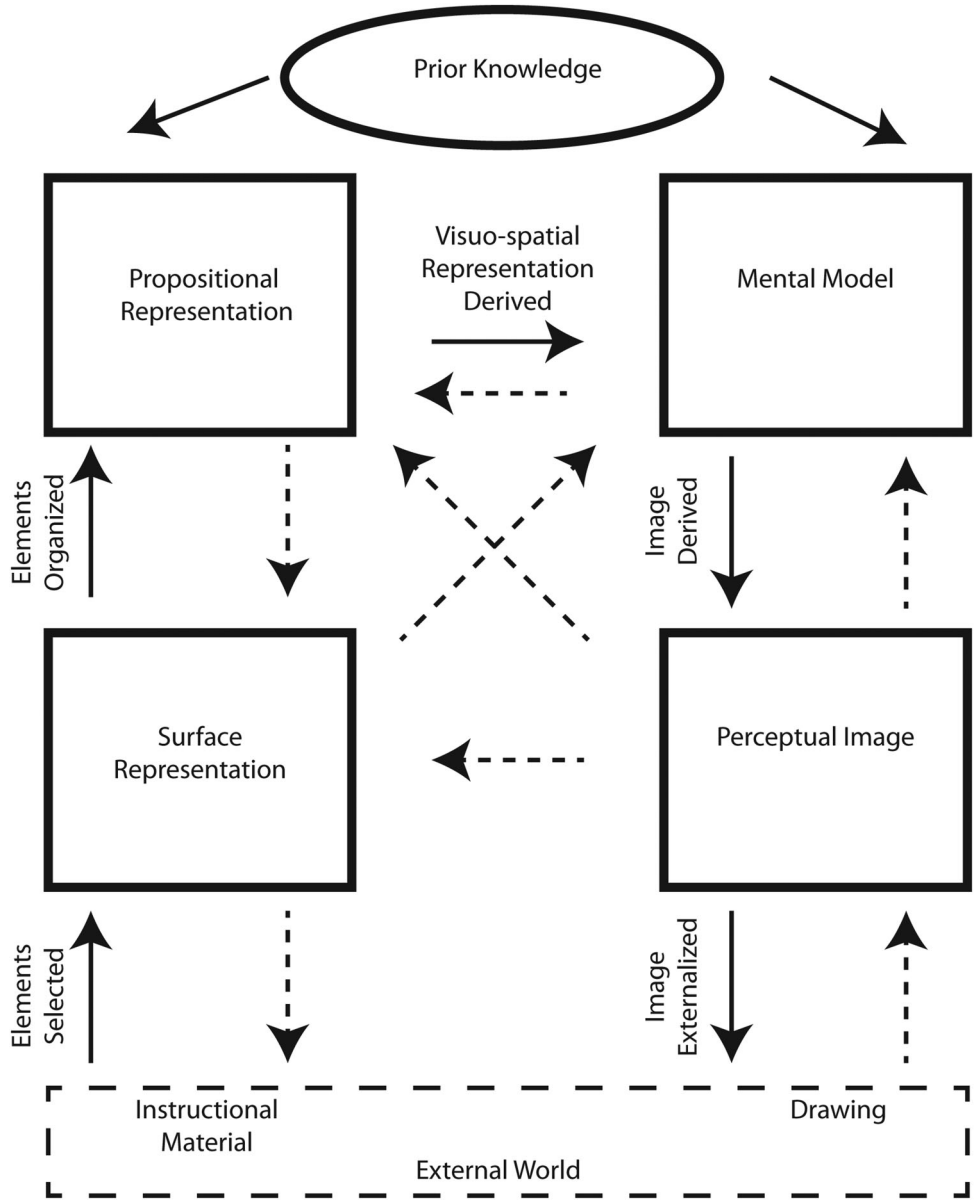

Figure 2. The Cognitive Model of Drawing Construction (from Van Meter and Firetto 2013). This model describes the process of mental model formation through drawing.

through excavation wherein an understanding of the archaeological remains is an accretive process that can change and grow. Part of this process is the written and visual documentation of the archaeological remains, which co-constructs our understanding of these remains. Examining drawing in particular allows us to unpick the creation of mental models in general and more specifically within archaeology.

Drawing and mental models

Drawing has been examined by educational psychologists as a method for enhancing learning outcomes. Learner-generated drawing is a strategy that allows the construction of an internal, nonverbal representation (i.e. a mental model) that translates across modalities to achieve a learning goal (Van Meter and Garner 2005, 286). Learners create such representations by selecting key elements of the external representation, organizing these representations internally, and integrating them into referential connections to link verbal and nonverbal representations (Van Meter and Garner 2005, 316).

The Cognitive Model of Drawing Construction (Van Meter and Firetto 2013) describes the cognitive processes underlying drawing as a method for better learning outcomes. Van Meter and Firetto argue that learners benefit from drawing because they "must generate a new conceptual representation as well as connections between the new representation and prior knowledge" (2013, 250). Figure 2 represents this model; the arrows in the figure indicate reflexive feedback cycles indicating a return to source material or previous information, showing a recursive process rather than a simple linear sequence in moving between the source material, mental model, and the eventual expressed model (Van Meter and Firetto 2013). A full account of this process is described by Van Meter and Firetto (2013), but critical to this discussion is their identification of drawing as a "forcing function:" the drawing cannot progress unless the source material has been fully understood, causing the person undertaking the drawing to exercise metacognitive awareness and control (2013, 259).

While it is not an exact analog, as archaeologists perform both sketches and technical scale illustrations, we found research on drawing in the geosciences illuminating and

Figure 3. Drawing study I, showing drawing by-hand, drawing on the tablet without a photograph, tracing a photograph on the tablet, and heads-up digitizing by tracing a photograph off-site. In photos: Holly Wright, Lesley Collett, James Taylor, and Helen Petrie.

relevant to understanding drawing in archaeology. Research building upon the cognitive model of drawing construction has shown that drawing 2D sections through 3D geoblocks in geology can improve the ability to understand 3D relationships (Gagnier et al. 2017). Further, Jee and colleagues (2014) found that the structure and content of sketches is reflected by relative expertise in the subject when students sketched rock formations. As such, sketching has been framed as vital to learning in STEM education, as it has been shown to increase engagement, deepen understanding of complex concepts, and encourage creative reasoning (Ainsworth, Prain, and Tytler 2011). Drawing supports better learning and reflects what has been learned. Simply stated, drawing forces one to create an external representation of a conceptual model (i.e. an expressed model), and this transformation produces a better understanding of spatial relationships (Jee et al. 2014; Gilbert 2005). Drawing forces you to understand and describe the subject under scrutiny.

Drawing Studies

Fieldwork study I: contextual inquiry

Our first study with field drawing was a contextual inquiry (Beyer and Holtzblatt 1997) with project members drawing an elevation by-hand and with a tablet of one of the historic walls within the King's Manor in York. Contextual inquiry is a lightweight form of ethnography which involves asking participants to do their typical "work," observing and asking questions to understand the work while it is underway. Prior to this study, we examined a variety of drawing programs compatible with Microsoft Surface Pro tablets before settling on ArcGIS Pro for its translatability to other archaeological workflows. Observations were made by Petrie, particularly regarding the physical posture of archaeologists as they interacted with drawing boards and tablets. The archaeologists explained their previous experience with various forms of technology and drawing, talked Petrie through their tasks, and answered her questions. The following four activities were investigated during the contextual inquiry: 1) drawing by-hand (Figure 3A), 2) drawing on the tablet without a photograph (Figure 3B), 3) tracing a photograph on the tablet (Figure 3C), and 4) heads-up digitizing by tracing a photograph off-site (Figure 3D). The wall selected for the study had several instances of repair and contrasting materials, which were observed and discussed in more detail as the inquiry progressed. It became clear that issues of relative expertise, the proximity to the subject of the illustration, and the general physicality of the interaction were important to observe during more formal investigations. This initial study was used to inform the Aide Mémoire Project research questions moving forward: does digital recording change how archaeologists see, understand, and interpret archaeological materials? What is the nature of archaeological expertise? It also suggested that drawing might shape how archaeologists form mental models to identify and interpret traces of past action. This will be more fully described below.

Fieldwork study II

Our second fieldwork study was conducted during the 2019 Elizabeth Castle Jersey Project (ECJP) excavations in Jersey, UK. The ECJP is a multidisciplinary, student-led, public-engagement-focused fieldwork research project run by a team from the University of York's Department of Archaeology, which sought to understand the significance and

interpretative potential of both the standing Hospital site and the site of the former (now demolished) Old Barracks (Cooke et al. 2019). The ECJP provided a good opportunity to work ethnographically with a small team in controlled conditions to make a clear comparison between traditional analog drawing practice and digital tablet-based approaches in the field. Once again we used ArcGIS Pro on Windows Surface Pro 3 tablets; ECJP member Helen Goodchild helped to develop a digital recording workflow within the project's intrasite GIS, which deliberately emulated conventional analog modes of recording. The GIS was therefore set up with digital graph paper to enable the creation of scaled offset drawings to be imported directly into the project's spatial database. This meant that ECJP students and staff members were essentially familiar with the desired output, minimizing the differences between the digital and the conventional analog media. Students were given a briefing and some training beforehand and asked to play with and familiarize themselves with the approach under supervision. Aide Mémoire members observed, photographed, and interviewed students and ECJP staff members while they were using the digital and analog recording techniques.

It was very noticeable that some of the students took to the digital drawing method much more quickly than others. This appeared to be due to previous experience with using tablet computers. Also, students often transferred particular techniques (e.g. counting and calculating scales) from analog drawing to digital drawing which were not particularly appropriate. The tablets were considerably more difficult for students and experienced staff members to handle in the field. Some of these difficulties are relatively well-known regarding digital recording in the field; students worried about damaging the tablets, the shape and size of the tablets made them awkward and not easy to balance on their knees, hip, or stomach for drawing, and glare on the screens forced students to retreat under shade, away from the active excavations (Figure 4). These issues meant that the students appeared to be spending more time and effort thinking about the tablet and not on the activity of drawing. This divided their attention, which impeded interpretation and the development of a mental model of what was being drawn. We initially thought these problems could be overcome with greater practice and confidence when drawing digitally, but our further studies contradicted this assumption, as described below.

Figure 4. ECJP staff members James Taylor and Catriona Cooper drawing with a Surface Pro.

Artifact illustration studies

During our fieldwork studies, we were able to observe how archaeologists engage with digital drawing under adverse conditions. Being outside and away from a stable surface introduced significant distractions when trying to draw on a tablet. Our next phase of studies examined archaeological illustration inside at a table. This was undertaken to remove the adverse conditions and miscellaneous contexts being illustrated (walls, cuts, etc.) introduced by working alongside an active field project but to also engage with another significant area of archaeological drawing, that of artifact illustration. We conducted the first study with archaeology students and the second with professional archaeological illustrators (defined as having 5+ years of professional practice). Observing professional illustrators would allow us to mitigate the perceived difficulty in using digital tools that we had noted in our previous studies, as they were all highly conversant in using tablets and computers.

During both studies, the subjects drew artifacts digitally and using a pencil and drawing film, with half starting with pencil drawing and half starting with digital drawing to counterbalance practice or fatigue effects. While they drew, Aide Mémoire Project researchers observed their methods and asked participants to undertake a concurrent verbal protocol or to "think aloud" (Dumas and Redish 1999). This involves asking the participant to articulate their thoughts as they do their task, explaining what they are doing, why they are doing it, and, in this case, how they are developing an understanding of the artifact. A researcher would prompt the participant with appropriate questions when needed, trying not to interrupt the work on the task. This is important, as often when the task becomes difficult (but interesting to the researchers), the participant stops talking in order to better concentrate. This technique is often used in the evaluation of new interactive systems and can be very helpful in eliciting a person's mental model of a system. The professional illustrators were also asked to perform the NASA Task Load Index, which will be described in greater detail below. At the conclusion of each study, we hosted a semi-structured focus group discussion with the researchers and participants to reflect on their experiences during the study. Finally, though the number of participants in these studies seems low, this is not unusual for intensive research, wherein hours of observation, evaluation, and discussion are leveraged against broader studies with many more participants, such as our survey.

Artifact illustration study I: archaeology students

There were four participants in the first iteration of the illustration study, which focused on archaeology students. Each participant was asked to draw 2–3 different artifacts, counterbalancing the order in which they did hand drawing (Figure 5A) and used a digital tablet (Figure 5B) and recording the experience of each type of drawing by completing a short questionnaire. This questionnaire gathered quantitative data regarding age and experience and qualitative data regarding their experience and understanding of the artifact before and after drawing the artifact. Researchers then asked participants to engage in the think aloud protocol while they were drawing, followed by the focus group discussion at the close of the study.

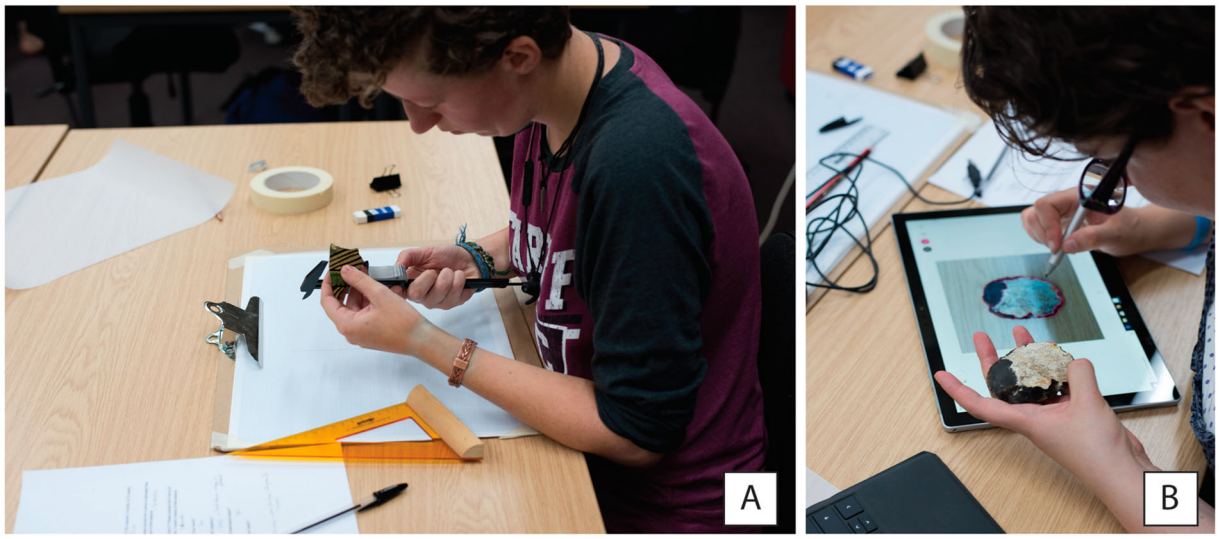

Figure 5. By-hand and digital artifact drawing study with students.

When compiled, the comments and observations from the study showed differences in how the participants understood the artifact before and after drawing, their stated understanding of the affordances of drawing and technology, and how technology changed their embodied experience and interaction with the artifact. When describing the artifact before drawing it, participants generalized, giving descriptions such as: "The object is a lithic around 15 cm in diameter that fits in the palm of the hand and is oval shaped. One face is almost entirely smooth, and the other side has a rough surface. The edges of the object are jagged and sharp." After drawing the artifact, the descriptions become more detailed and more tied to the sensorial experience of handling and close observation: "The surface of the smooth parts of the lithic are hard and smooth, with the lighter face of the object being chalky and rough feeling. Slight ripples and manufacturing marks are visible on the surface." This could be attributed to a longer time of exposure to the artifact, including more time handling it. One participant stated, "I understand all the better what the sherd is from, but with more time looking at it, I would have noticed this anyway." Yet, each participant observed that they understood the artifact better after drawing it either digitally or by-hand, particularly when drawing lithics. One participant stated: "I have a better appreciation for the subtle ripples and manufacturing marks that are present on the object's surface after trying to draw them. I also feel I better understand the shape and feel of the object (how it fits in the hand) after trying to capture this."

When asked, "Do you feel like other methods would give you the same or a different understanding of the artifact?" answers were mixed, with several participants noting that photography or photogrammetry would better capture color and volume with more accuracy. Generally, digital methods of visual capture were seen as overwhelmingly positive, with one participant noting, "I would probably not notice all the details of the artifact with the other methods, but the main information (size, shape, decoration, etc.) would still be included." More insights regarding the utility of drawing were noted by the researchers in their discussions with participants. One participant noted that it was "important to have the physical artifact rather than a photo, as diagnostic aspects can be hard to see in a photo."

Critically, researchers observed that participants interacted with the artifact far less when drawing the artifact digitally. They did not pick up or handle the artifact at length, as they did with the analog drawing. This was exacerbated when participants chose to take a photograph of the artifact and traced the photograph on the tablet to create the drawing. One participant noted that they felt like they were "looking at the image too much and not the artifact; (I) need to go back and see detail in the artifact; (I) can't see it in the photo." One participant was observed neglecting the original artifact entirely, tracing all the details on the photograph instead of selectively drawing to interpret the object. Most of the participants altered their posture after they shifted from drawing by-hand to digitally, though the tablet set-up was not substantially different to drawing on drafting paper. One noted they found themselves holding the stylus more lightly and farther away from the tip than they would with a pencil. Amongst these inexperienced illustrators, analog and digital illustration took approximately the same amount of time.

Artifact illustration study II: experienced illustrators

The second iteration of the study was conducted with five archaeological illustrators with at least five years of professional experience. Many of the practical details of the study were the same as the first iteration, including the location, the sequence of the day, the artifacts, and the researchers undertaking the study. In contrast with the use of ArcGIS on Surface Pro 3 tablets used in our previous studies, participants brought their own digital set-up and drawing materials, though spare stationery and computers were available, and a few made use of these.

Participants drew 3–4 artifacts, both by-hand (Figure 6A) and through digital methods (Figure 6B). They filled out the questionnaires, were observed and participated in the think aloud protocol, and there was a focus group discussion at the end. We noted in our previous studies that digital drawing was found to be more difficult than by-hand drawing, so in this iteration, we decided it would be useful to understand how much more difficult it was perceived to be. To do this, we employed the NASA Task Load Index of physical and mental workload (Hart and Staveland 1988) to quantitatively measure the relative difficulty of drawing digitally.

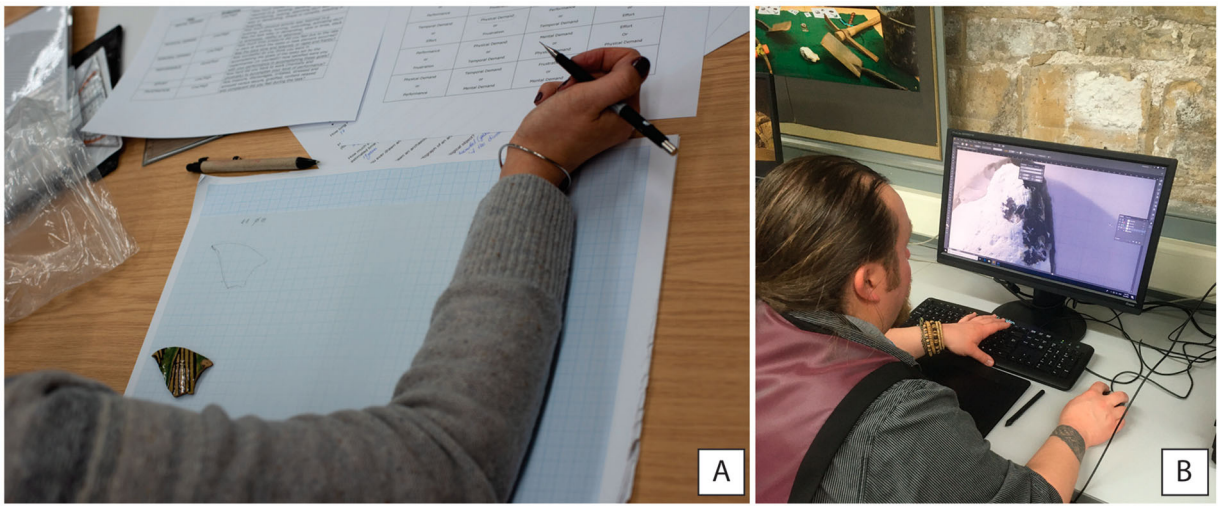

Figure 6. Experienced illustrators drawing by-hand and digitally.

The NASA Task Load Index (known as the NASA-TLX) is a two part questionnaire widely used in human-computer interaction work to measure six different dimensions of subjective experience of physical and mental workload (Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration; see Table 1 for explanations of each dimension) of any task or type of task (Hart and Staveland 1988). In the first part, participants are asked to consider all pairs of the six dimensions for a particular type of task (e.g. drawing digitally) and select which is more important. This creates a set of weightings which represent the person's individual mental model of their subjective experience of the workload of that particular type of task. Then the participant is asked to undertake one or more instances of the task (in our case, to draw three or four artifacts digitally) and then rate each specific task on the six dimensions. The weights from the first questionnaire are then used to calculate the relative importance of the different dimensions of task workload for each participant. The tool allowed the researcher to more precisely examine the differences in workload between by-hand and digital illustration. Figure 7 shows the average ratings of instances of the two drawing types for one of the artifacts each participant drew.

Table 1. NASA TLX dimension definitions, derived from Hart and Staveland 1988.

Dimension	Endpoints	Description
Mental Demand	Low/High	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/High	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task element occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/ Poor	How successful do you think you were in accomplishing the goals of the tasks set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

With only five participants, it would seem unlikely that overall significant differences would be revealed. However, there was a significant difference in Frustration, with digital drawing being significantly more frustrating than analog drawing (a statistical test, the Wilcoxon related samples signed rank test, revealed this significance: $W = 15.00$, $p < 0.05$). There are intriguing hints that Mental Demand and Physical Demand might be lower in digital drawing, whereas Temporal Demand is higher. For four of the five participants, Mental Demand was lower in digital drawing, suggesting that they are very skilled with their digital drawing hardware and software, even though they find it frustrating. This suggests it is not meeting all their needs and lacks usability. Three of the participants found less Physical Demand with digital drawing than analog drawing; the others found no difference between the two, again suggesting that the experienced participants are very comfortable with the digital experience. Two participants found digital drawing created greater Temporal Demand, while one found that analog drawing created greater Temporal Demand, and two participants found no difference between the two. Yet, this dimension may have been difficult for participants to interpret in the context of the study, as their comments suggested that there was significant Temporal Demand in the archaeological drawing task, but this is coming from external factors. These results show that using the NASA-TLX measure with larger samples of archaeologists, with different levels of drawing expertise, will likely reveal more useful information.

The combined discussions, observations, and questionnaires gathered from professional illustrators were similar to those of the participants with relatively little experience. There were differences in their understanding and interactions with the artifacts both before and after drawing them, as well as differences between by-hand and digital drawing. The observations made before drawing the artifact were more detailed, with more descriptive visual language, such as "glazed pottery sherd, no rim, ridge 'wheel' mark near top, light green transparent glaze inside surface,

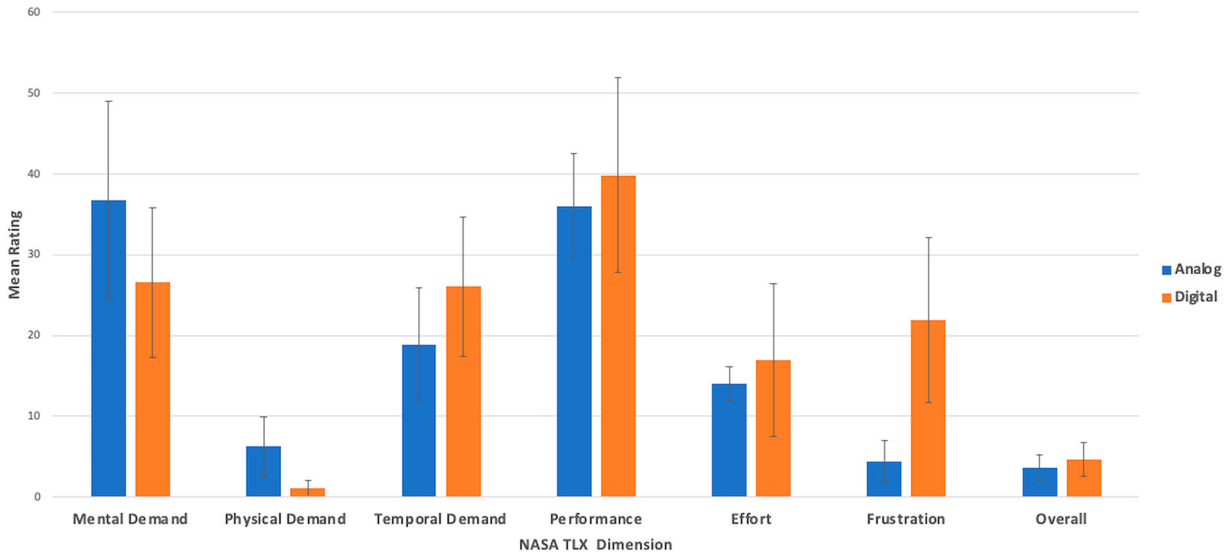

Figure 7. Mean ratings of NASA-TLX dimensions of mental workload for analog and digital drawing.

scratch/mark on inside bottom (prefiring). Outside—transparent glaze with green tinge, green semi-opaque thick stripes, and brown thin stripes, two of which you can see terminate at edge of break." Even so, participants were able to elaborate upon these observations after drawing the artifact, for example noting worked edges on lithics that were unnoticed before illustration: "The retouch on the working edge was more complex than a casual examination might reveal." Similarly, to the participants in the first illustration study, physical interactions with the artifact diminished during digital illustration, when compared to interactions while illustrating by-hand.

The professional illustrators engaged in what could be termed "meta" discussions while illustrating, perhaps indicating their relative experience decreased the cognitive load of drawing artifacts. They noted problems particular to their profession; some of these were similar to the labor discussions in the subsequent survey about accelerating workloads and little time to deeply consider the sites or artifacts they were illustrating. They considered interpretation of artifacts to be primarily the work of the artifact specialists and that the visual interpretation was co-constructed with the specialist to show specific points of emphasis. Several of the illustrators noted that they felt "stressed out" by the observational study's perceived lack of parameters and uncertain audience for their illustration. For example, they were accustomed to very strict time constraints and exact publication standards, and so the level of visual elaboration in their drawings was difficult for them to determine. Since the advent of digital tools and methods, the illustrators observed that the quality of drawings coming to them from archaeologists working on excavations had greatly diminished. They observed that some forms of digital recording, such as the use of Differential GPS on site, were difficult to translate into attractive, publication-ready images and that their work as illustrators was siloed away from fieldwork.

To a certain degree, division between by-hand and digital illustration was much less pronounced in the second illustration study, as all of the participants had developed a digital workflow, with some essentially working entirely digitally. Yet they all agreed that by-hand drawing was essential to learning how to understand artifacts and sites. They also agreed that there should be much more training in drawing at the university level and amongst fieldworkers.

From these studies, we understood that the physical interactions with digital technology are more difficult in field conditions but still were more difficult in a more controlled environment amongst both students and very accomplished practitioners. Yet, our sample was relatively small; to more fully understand the perception of both digital and by-hand technical illustration, we performed a large-scale online survey.

Survey

After completing the intensive fieldwork and illustration studies, it was important to gain a broader contextual understanding of how drawing in archaeology is currently perceived across the discipline. To accomplish this, we conducted an online survey in May–June 2020. The survey was distributed via social media and was therefore biased toward archaeologists who are active online, though there may have been greater general uptake, as many archaeologists were in lockdown due to pandemic restrictions. The survey received 274 responses, but 39 responses were incomplete or answered in less than 2 minutes (mean completion time was 18 minutes, 23 seconds) and so were discarded, leaving a sample of 235 responses.

The demographics of the sample are summarized in Table 2. The sample is well balanced for gender and covers a wide range of ages and roles across archaeology, as well as length of involvement in the field and amount of fieldwork experience. The majority of respondents had trained in British and American methodological traditions in archaeology but with nearly a quarter (23.8%) having trained in other traditions, including German and Italian.

Respondents were asked to rate how much they liked drawing in general and drawing in archaeology specifically, using a five-level rating scale (from "not at all" to "like a lot"). Ratings were skewed towards the positive end of the scale for both ratings, so nonparametric statistics were used. The median rating for drawing in general was "somewhat like" (4.00, interquartile range: 2.00), and for drawing

Table 2. Demographics of the survey sample.

Gender	Participants
Women	118 (50.2%)
Men	107 (45.5%)
Nonbinary	7 (3.0%)
Prefer not to answer	3 (1.3%)
Age	
18–25	58 (24.7%)
26–34	55 (23.4%)
35–44	61 (26.0%)
45–54	36 (15.3%)
55+	24 (10.2%)
Prefer not to answer	1 (0.4%)
Role*	
Undergraduate student	27 (11.5%)
Postgraduate student	59 (25.1%)
Academic archaeologist	76 (32.3%)
Commercial archaeologist	42 (17.9%)
Other professional archaeologist	7 (3.0%)
Other heritage/non-profit professional	6 (2.6%)
Volunteer archaeologist	6 (2.6%)
Archaeological illustrator/photographer	5 (2.1%)
Prefer not to answer	7 (3.0%)
Length of Involvement in Archaeology	
Less than 3 years	23 (9.8%)
3–6 years	43 (18.3%)
6–10 years	41 (17.4%)
10–15 years	32 (13.6%)
15–20 years	26 (11.1%)
Over 20 years	67 (28.5%)
Amount of Field Work	
Less than 12 months	78 (33.2%)
1–3 years	39 (16.6%)
3–5 years	38 (16.2%)
5–10 years	29 (12.3%)
10–15 years	21 (8.9%)
More than 15 years	26 (11.1%)
Prefer not to answer	4 (1.7%)
Archaeological Tradition*	
British	83 (35.3%)
USA	43 (18.3%)
German	14 (6.0%)
Italian	9 (3.8%)
Other	33 (14.1%)

*Respondents could give more than one answers, so totals may be greater than 325/100%

in archaeology, the median rating was "like a lot" (5.00, interquartile range: 1.00). The ratings for drawing in archaeology were significantly higher than for drawing in general (repeated samples Wilcoxon Signed Rank Test, $W = 5.58$, $df = 225$, $p < .000$), although there was a strong correlation between the two ratings (Spearman $r = 0.51$, $p < .000$). Thus, in general, respondents like drawing but like drawing in archaeology even more.

Almost all respondents had drawn an archaeological context or feature by-hand (94.5%), but only a little over half had drawn a context or feature digitally (59.3%). Whether respondents had experience of digital drawing depended on their level of experience in archaeology. Table 3 shows that students, both undergraduate and postgraduate, were less likely to report having drawn digitally, and this difference was highly significant ($\chi^2 = 29.31$, $df = 5$, $p < .000$).

There were 122 respondents who had experience of both drawing by-hand and drawing digitally. Of these, just over 50% prefer drawing by-hand (54.8%), just over a quarter have no preference either way (28.7%), and 16.4% prefer drawing digitally (Table 4). Looking at the different levels of experience, students show the highest percentage with a preference for digital drawing and academic archaeologists the lowest percentage, but the sample sizes are now relatively small, and these differences are not significant ($\chi^2 = 5.14$, $p = .74$).

For the open-ended questions in the survey, we conducted a reflexive thematic analysis (Braun et al. 2019) wherein three people coded the answers to find emerging themes and to compare perceptions of these statements. When asked "Do you feel like other recording methods (photography, photogrammetry, 3D scanning) would give you the same or different understanding of the context/feature? Why?", most respondents provided meaningful answers to this question (83.8%) and framed their answers within the broad categories in Figure 8. Each category will be described further below.

Differences

Perhaps led by the question, many respondents framed their discussion of by-hand and digital drawing through highlighting the differences between the various techniques. This was dominated by discussions of accuracy regarding digital technologies, but drawing by-hand was perceived to have greater interpretive power. One respondent discussed their wide experience with digital technologies but still gave primacy to by-hand drawing: "I am involved with all of these other processes including photogrammetry, structure from motion, 3D scans, drone based multispectral imaging, etc., as well as hand drawing. The hand drawing is still the most involved and feature-focused activity."

Another response emphasized agency and interactivity: "Photography and 3D scanning create a different level of interaction with the archaeology. It feels much more passive, versus when you hand draw, you have to interact with the archaeology in front of you. In the attempt to make your hand drawing as accurate as possible, one must have a deep understanding of the relationships each feature may have—or not have—with one another."

Though many respondents highlighted a perceived contrast between digital and by-hand drawing in terms of objectivity, a few responses discussed the differences between the

Table 3. Percentage of respondents with experience of digital drawing.

	Undergraduate Students	Postgraduate Students	Academic Archaeologists	Commercial Archaeologists	Other Professional Archaeologists	Others
N	7/27	24/55	54/74	30/42	10/12	6/11
%	25.9	43.6	73.0	71.4	83.3	54.5

Table 4. Percentage of respondents preferring digital drawing or drawing by-hand or having no preference.

	UG and PG Students	Academic Archaeologists	Commercial Archaeologists	Other Professional Archaeologists	Others
Digitally	25.9	9.8	21.4	20.0	0.0
By hand	51.9	60.8	53.6	30.0	66.7
No Pref.	22.2	29.4	25.0	50.0	33.3
Number	27	51	28	10	6

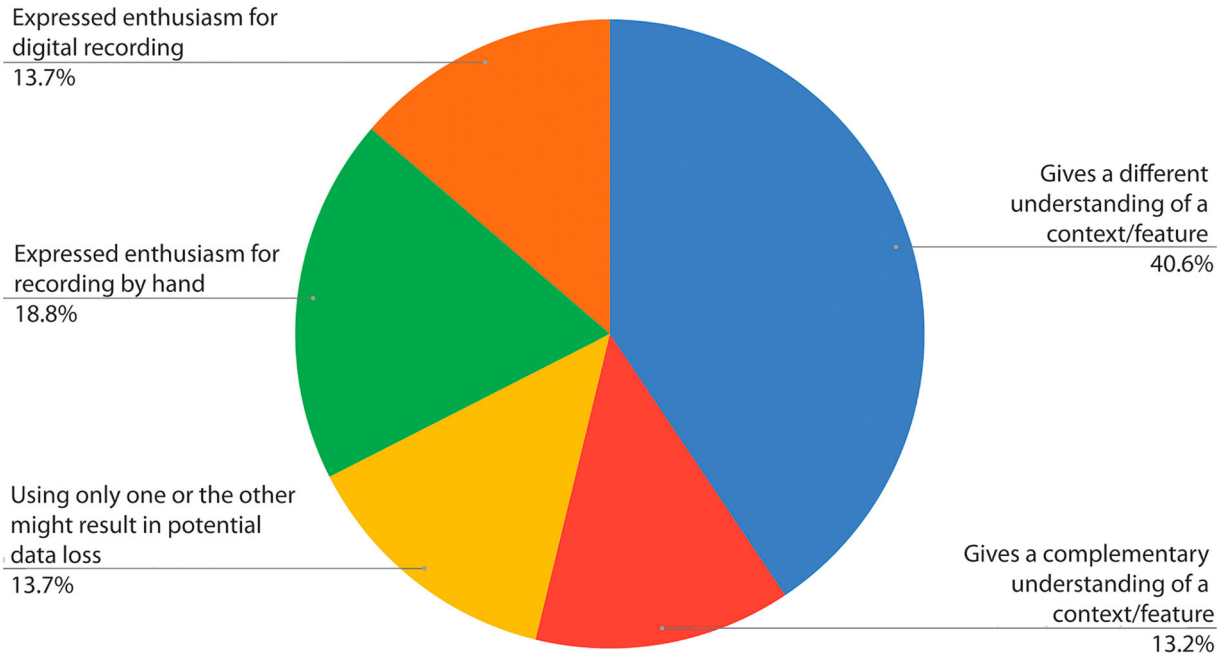

Figure 8. Categories revealed by reflexive thematic analysis categories and their relative proportion of answers.

techniques but emphasized that both are subjective: "Photography, photogrammetry, 3D scanning all provide different understandings of the context/feature—all methods are subjective forms of documentation, and given their different techniques and equipment used, guide and alter how the archaeologist will interact with and record the feature."

Complementary

Many found that while the methods of recording were different, they were complementary and should be integrated: "I think both digital and manual have different benefits. Manual feels like a more reflective process that helps in the interpretation process, whereas digital allows more details to be highlighted and revealed." Yet even when multiple methods were considered, many noted that hand drawing should be preserved; for example, "I think 3D scanning gives a better overall impression of the context/feature, but hand drawing helps me personally wrap my head around it."

Loss

Some answers, though framed within a discussion of difference or integration, emphasized loss as a potential outcome of exclusively using either digital or by-hand recording. This loss was considered either in terms of data loss or, compellingly, loss of understanding, memory, or connection. As one respondent stated: "Hand drawing provides an intimate knowledge of the archaeological remains. Digital provides more detail, however, provides less connection."

Drawing by-hand takes time, and time spent recording is perceived to improve understanding: "I do not believe that photography gave me the same understanding of the feature, because I was not able to spend the time with it. Fifteen minutes of interaction with the screen of a digital camera is a lot less intensive than four hours with pen, paper, and a plumb-bob. After drawing a feature, I could recall from memory the placement of every stone and the shape. A few days after taking a photograph, however, I may not recall if I have even photographed that feature."

Storage formats were also seen as a potential risk for the longevity of archaeological data: "The increasing tendency for replacing the drawn record with 3D digital recording in contract archaeology has some drawbacks, in terms of the lack of interpretation of archaeological remains within the primary record and potentially the long-term storage and accessibility of archaeological archives."

These concerns will be further discussed below, but it is worth noting here that this is a key problem identified by archivists of archaeological data and is the subject of its own research area. That archaeological interventions are often non-repeatable, and are now increasingly being documented using digital media and formats that rapidly become obsolete, poses major problems for our understanding of the archaeological record in the future.

Interestingly, loss in terms of fidelity and proximity were also noted in terms of both digital and by-hand recording. In terms of digital: "Photography, photogrammetry, and 3D scanning are incredibly valuable, but there is nothing like experiencing a feature in the field. Colors can often be distorted in photographs. Photogrammetry and 3D scans can feel divorced from context. DGPS is an interpretation."

Others regarded the downside of by-hand drawing as introducing potential inaccuracies by a fallible archaeologist—"On-site drawing is important for understanding and 'seeing' the features or stratigraphy, but a (good) photograph does not transfer any mistakes made by drawing"—and compared techniques to each other—"3D scanning and photogrammetry allow recording in 3 dimensions, can include things that might be missed by-hand, also color, etc., in photography."

Enthusiasm for methods

Some respondents were emphatically in favor of either by-hand or digital drawing. Enthusiasm for digital recording was primarily due to the perception of objectivity as

Table 5. The perception of digital and by-hand recording in archaeology.

Method	Perception
Digital	distance, speed, accuracy, objectivity, public engagement
By-hand	slowness, understanding, intimacy, subjectivity, aesthetics, depth

discussed above. Those who supported drawing by-hand spoke passionately of connecting with the archaeological remains, the aesthetics of drawing, and their satisfaction with creating the drawing: "There is no substitute for time on-site looking at the feature … Drawing by-hand gives time for this, constantly looking at a feature in changing light, weather conditions, etc. Digitizing only gives one view of this, with limited subsequent site time. There is something very satisfying about a hand-drawn drawing." Another contrast was seen in terms of the perspective that drawing and digital recording can offer: " … A drawing is analytical. It offers visual perspective (e.g. a section of an object/feature) that photography and other methods cannot. Drawing includes an 'inside' view, while the other methods almost exclusively provide a 'surface' view. Second, a drawing is built heavily on the illustrator's personal perceptions. Digital recording methods are less interpretive." " … The reason hand drawing is such a powerful interpretive tool is that in placing a line upon the page, you're forced to confront the stratigraphic relationships—this works equally well for a ditch section, a building plan, or an artifact like a piece of worked flint. You can't fudge it. I think sometimes photography/photogrammetry allows detail to obscure clarity. You can get away with not understanding site formation processes if you have a nice image. But in hand drawing, it becomes clear very quickly, to yourself and to others, if your interpretation doesn't work."

The perception of by-hand and digital recording in archaeology as reflected in the Aide Mémoire Project survey is summarized in Table 5; digital recording is associated with quick, accurate, objective recording, whereas by-hand recording is valued for care, slowness, aesthetics, and improved understanding. In addition to illuminating the perception of drawing in archaeology, it also revealed the wide array of technologies under the remit of digital recording (Figure 9).

Archaeologists describe workflows involving tablets, laptops, auto-tracking total stations, GPS, both on-site and in the office, digitizing from photos, 3D models, and by-hand drawings in almost every available CAD, GIS, and drawing program available now or in the past. One of the participants stated, "To be honest, I am not sure what counts as digital drawing. I have done photogrammetry and then digitized the features and structures." This complicates any easy comparison between methods, as the perceptions of archaeologists regarding digital recording will be informed by diverse technologies. It also defies more holistic strategies, as using by-hand drawing alongside each of these other technologies would be beyond the time and funding limits of many projects.

Finally, the survey provided some unexpected insights into the many contexts that archaeological recording inhabits. While we were trying to cast a large net, we failed to consider all the affordances of archaeological recording. One stated that "photogrammetry is a good and affordable solution for underwater archaeology." Disability was noted as an important consideration by a few respondents: "I struggle to draw, as I'm dyspraxic" and "find it really frustrating and difficult," whereas a respondent who "has no depth perception" found drawing helpful. Issues regarding craft and labor were apparent in the survey. There were several calls to improve training in drawing for archaeologists, with many emphasizing the importance of learning by-hand drawing before moving on to digital technologies—" … One of my biggest concerns in this area is for students who begin with digital methods for recording. Part of learning to draw by-hand is learning to see like an archaeologist at the same time. I fear that when the first instinct is to mash a button and look at a screen, you miss some of the basic skills you learn when you have to actually engage with an archaeological context or artifact using all of your senses." In commercial archaeology, by-hand drawing was seen as "typically the first occasion to slow down and really look and think about what you have in front of you. This process is almost entirely lost with digital methods."

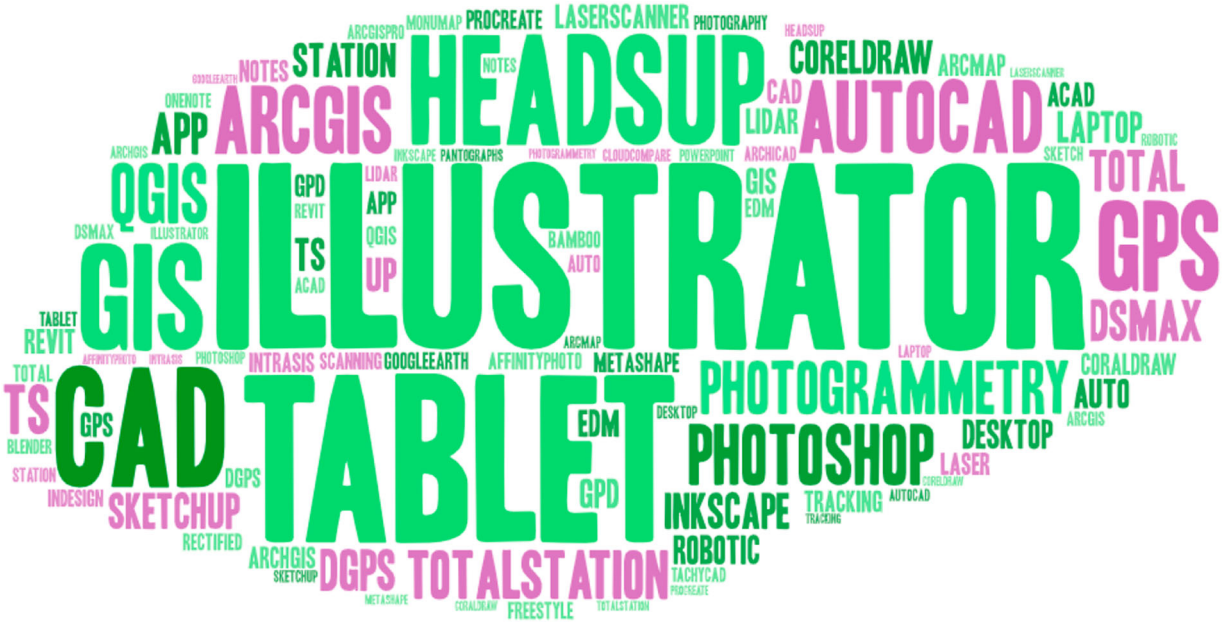

Figure 9. Word cloud showing the variety of technologies archaeologists are using for digital recording.

By some, by-hand drawing could be framed as resistance to an increasingly difficult work environment and digital recording leading to degradation of craft: "As a commercial archaeologist, I have become increasingly uncomfortable with attempts to digitize recording in the field that have been pushed in recent years. Some digital techniques do work very well and can easily be undertaken with minimal costs, such as the photogrammetry of skeletons, walls, etc. However, most of the time, digital recording methods are perceived to be efficient but often are not and result in a loss of craftsmanship—perhaps not quite the right word, but I mean the sense of pride in your work. Commercial archaeologists are constantly forced to work under stricter and stricter deadlines, and recording is often one of the only chances in the day to slow down and rest your back. Because of this and the feeling of marginalization, attempts to digitize recording are often viewed with resentment."

With regard to the formation of mental models to understand archaeological remains, some respondents hinted at the potential implications of removing by-hand drawing for digital recording: "I find it's much easier in my experience to simply switch off and fall into the mechanical click-click of photogrammetry" and "Drawing a context is like reading a page in a book, photographing (and subsequent tracing) is like photocopying that page." Yet, there is still much to untangle, as one respondent pointed out: "I wonder how helpful the analog/digital dichotomy is anymore. At this stage, basically all of us who draw things by-hand also do some kind of digital illustration to finish off our images for reports or publications." Bringing this survey data into conversation with our studies and the literature regarding mental models provides intriguing insights into archaeological knowledge creation.

Discussion

Our examination of drawing in archaeology has provided us with valuable insights into how archaeologists record and understand archaeological remains. The perception among archaeologists that drawing is both essential to archaeological recording and of great pedagogical importance is noted in our survey results. So too is the interest in digital methods to record archaeology and the idea that though these methods are not necessarily commensurate, both have value in the interpretation of archaeological remains. This perception was upheld within our studies, with by-hand and digital drawing offering different interactions and interpretations, generally corresponding to differing levels of experience. Based on these observations and the background literature of mental models and drawing, we can discuss how archaeologists use drawing to interpret archaeology, how digital technologies impact this interpretation, and how to make better use of digital technology to support archaeological interpretations.

While there have been several works that have investigated the history, poetics, and practicalities of drawing in archaeology, there has not been a systematic study of the contributions of drawing to archaeological knowledge production (for a full discussion of the literature regarding drawing in archaeology, see Morgan and Wright 2018). To understand the place of drawing in the creation of mental models in archaeology, we draw from the Cognitive Model of Drawing Construction (CMDC; Van Meter and Firetto 2013), as previously described. We have adapted their model (see Figure 2) to incorporate considerations in archaeological drawing (Figure 10). Similar to Figure 2, the square boxes indicate the archaeologist's internal knowledge representations (Van Meter and Firetto 2013, 254). The CMDC is based on verbal instructional material, yet we would argue that archaeological drawing is constructed in a similar way.

The archaeologist has an embodied encounter with archaeological remains, whether this is a context, a building, or an artifact. Certain elements of these remains are observed and sub-selected, then organized into a propositional network that describes the relationships between the structural elements (Van Meter and Firetto 2013, 255). This interaction is mediated with collaborative interpretation, i.e. archaeologists discussing the interpretation of archaeological remains with other archaeologists. These relationships are then coalesced into a mental model from this network, as negotiated through prior experience. The mental model is key to understanding how the different elements of the archaeological remains are related and what they may represent; this mental model "holds primary responsibility for the beneficial learning effects of drawing" by translating the mental model into a perceptual image (Van Meter and Firetto 2013, 255). Drawing standards, either formalized as in the single context recording system or as informal mores passed down as a miscellaneous legacy, encode the mental model as it is transformed into a perceptual model. Finally, collaborative feedback informs the re-interpretation and re-drawing of archaeological remains (see Edgeworth 2003). Note that there is the opportunity to revisit each of these stages, as represented by the arrows with the dotted lines.

Knowing how cognition interacts with knowledge creation, we can examine the impact of different recording strategies on the creation of mental models within archaeology. Then archaeologists can make informed decisions about their methodologies. If by-hand drawing is replaced with, for example, DGPS outlines of contexts, as has been documented in developer-led archaeology sites in the UK, does this replacement engage with the process of mental model creation to aid interpretation? This is particularly critical amongst archaeologists in the early stages of their career. As observed by many in our survey, and as demonstrated by our studies, technology has an even greater impact on the mental model creation of students and those with a relative lack of experience in archaeological recording. When the difficulty of drawing or interacting with technology is increased, comprehension of the archaeological remains, artifacts, and the stratigraphic record is reduced. For the very experienced illustrators, even though drawing was conceived of as easy, it was still significantly more frustrating than drawing by-hand.

This difficulty corresponds directly with the literature on the generative drawing principle in multimedia learning (Leutner and Schmeck 2014). Leutner and Schmeck note that while increased learning outcomes are achieved by students engaging in by-hand drawing using paper and pencil, they found diminishing returns when the process of creating the drawing resulted in "extraneous cognitive processing" (2014, 435). When the drawing conditions become more difficult, such as drawing on a computer without training, learning outcomes are diminished but still persist in greater strength than those produced without drawing at all (2014,

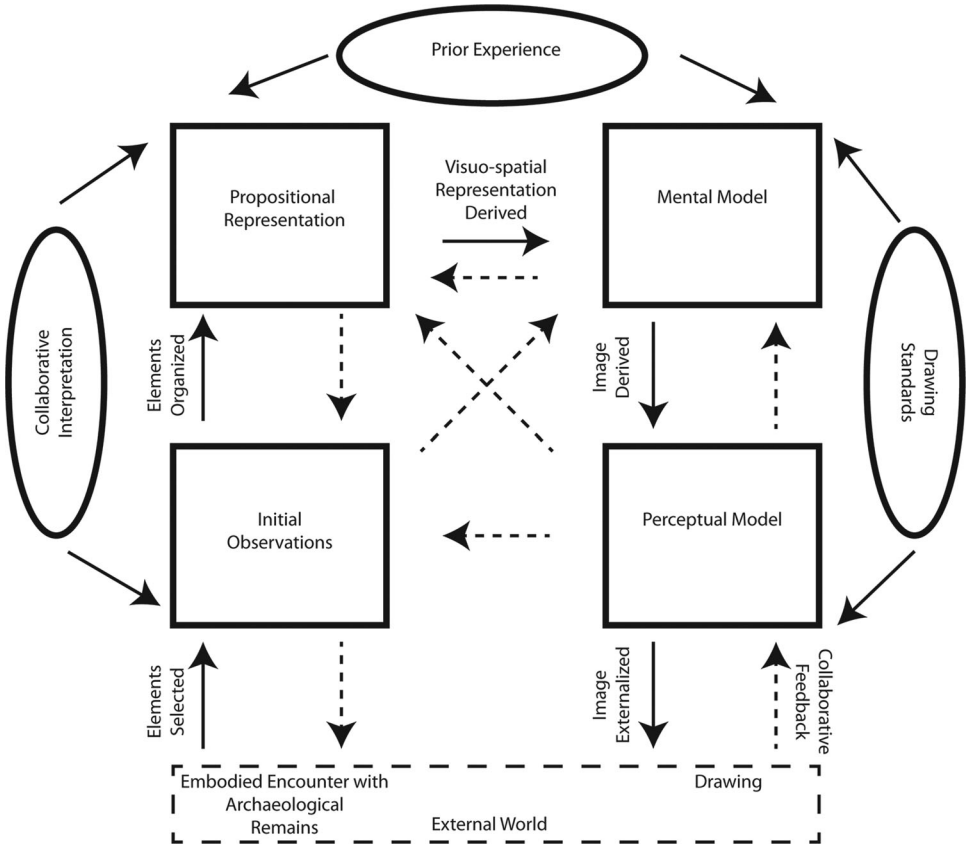

Figure 10. The cognitive model of drawing construction within archaeology.

443). There is further hope for positive pedagogical outcomes through digital drawing: Ginns and colleagues (2016) examined the role of embodiment on cognitive load (see also Glenberg 1999) by creating conditions wherein students traced existing drawings and then were tested on their knowledge. Students who had traced materials performed better on these tests than students who merely studied the materials.

Though much of this research would seem to imply that by-hand drawing should remain the gold standard, particularly by archaeological learners, there are also ways that we can integrate digital recording that may further positively impact learning. As observed by Taylor and colleagues (2018), having digital access to previous excavation data while in the field helps to support archaeological interpretation. Creating digital drawing systems that support the archaeologist may actually help increase understanding of archaeological remains; for example, during the observational study, we learned that the expert artifact illustrators had created a bespoke suite of digital tools that mimicked varied pen sizes for inking illustrations. Though translating material shapes to archaeological representational standards best supports the creation of mental models, even tracing these shapes on an existing rectified photograph, as described by Taylor and colleagues (2018), is better than not drawing the remains at all.

In addition to the learning and cognitive issues discussed above, the move from analog to digital drawing creates implications for how we will understand the archaeological record in the future. When an archaeological intervention, particularly excavation, is non-repeatable, field recording becomes the primary data, and with the increase of digital recording, the primary data that will need to be preserved will also be increasingly digital. Digital data is far more fragile than analog data, requiring regular mitigation as digital applications and storage formats are updated or become obsolete. The difficult truth is the majority of this data will be lost, as currently very little digital archaeological data is being archived in a sustainable way (Wright and Richards 2018).

Even for the small percentage that is archived, the move to digital formats such as 3D digital recording are exacerbating the sustainability problem. These formats create massive file sizes, which often require inclusion of interim formats and complex metadata to be understandable for future users. It represents a significant monetary and time investment to give this primary data a sustainable future and will inevitably result in archaeologists having to make difficult choices about what to archive, resulting in the loss of even more archaeological knowledge as we move forward with digital methods. It is going to skew the primary data record, favoring the methods that require the least amount of data cleaning and preparation, as well as the lowest storage costs.

Conclusions

At a time when educational psychologists are framing drawing as essential to the creation of robust mental models, archaeologists have been moving away from using drawing in archaeological recording. While the Aide Mémoire Project began with a relatively ambivalent stance regarding by-hand and digital recording in archaeology, this research overwhelmingly supports not just the continuation of drawing (either digital or analog) within archaeology but the increased use of drawing, not just for field recording and artifact illustration, but also within regular instruction and demonstration of key

concepts within archaeology. Much of the research on drawing within psychology was in support of understanding its impact on the educational outcomes of text-based learning or sketching, yet our research demonstrates the applicability of this research to archaeological learning. Archaeological pedagogy would do well to further support the integration of drawing at every stage of learning.

We conclude that there are significant pedagogical, academic, and professional implications to consider when removing or replacing by-hand drawing with digital recording in archaeological methodology. As such, we return to the question initially put forth in our review (Morgan and Wright 2018) of by-hand and digital drawing: what do we want drawing to *do* in archaeology? If drawing is removed entirely from archaeological recording, experienced archaeologists can still understand archaeological remains and transmit this understanding to others through their records. Yet, novices and students of archaeology might not be able to form mental models that support the understanding of these remains. As noted by a survey participant, "If drawing starts to be seen as more akin to transcription than to translation as a result of digital tools, I think we will lose perspective on our own processes of knowledge generation." If this crucial step is not preserved, future archaeologists may be able to proficiently use methods such as photogrammetry, but basic understanding of site stratigraphy will suffer. The research conducted by the Aide Mémoire Project also revealed important concerns regarding the labor implications of capitalism and using digital recording as a shortcut instead of supporting learning by archaeologists. These concerns are compounded with the implications for the future of the archaeological record; by moving to digital mediums and methodologies that require constant care and mitigation for the data to be accessible in the long term, digital short-cuts can privilege short term gains at the expense of longevity of data and enskillment in archaeology. Digital tools should support, not undermine, archaeological knowledge construction by archaeologists who use them (cf. Berggren and Gutehall 2018).

The interdisciplinary Aide Mémoire Project's research on drawing in archaeology has allowed us to propose a model of how archaeologists interpret archaeological remains and artifacts. We provided a firm foundation for understanding archaeological knowledge construction in general and through drawing. Drawing, as shown by this research, is central to this archaeological knowledge construction. Future research in the use of digital technologies to record and transmit interpretations needs to incorporate robust methods for understanding the impact of these technologies on archaeological knowledge construction and how to provide for the long-term care for that data. There are additional, important considerations in this research with regard to accessibility and disability, as noted by our survey participants. Though this particular research addresses archaeological recording, there are broader implications for understanding how mental models can be impacted by digital media and how expertise might change this relationship. Finally, as noted by a survey respondent, "We're never capturing reality; at least hand-drawings are unfailingly honest about that."

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